



# Australian Bureau of Statistics

## 1301.0 - Year Book Australia, 1988

ARCHIVED ISSUE Released at 11:30 AM (CANBERRA TIME) 01/01/1988

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## **DROUGHT IN AUSTRALIA**

This article has been contributed by the National Climate Centre, Bureau of Meteorology.

### **INTRODUCTION**

The incidence of drought in Australia to 1968 was surveyed in the 1968 Year Book No. 54. The purpose of this article is to bring that survey up to date with information to 1986 inclusive. While broadly summarising the material from the earlier article, the most recent widespread and severe drought in Australia, the drought of 1982-83, is given a special mention. Developments in the Australian Drought Watch Service, operated by the Bureau of Meteorology, and in the monitoring of variations in the climate that can lead to drought are also briefly described.

### **DEFINITION OF DROUGHT**

Drought in general refers to an acute water shortage. However the term is relative because water availability, which depends on supply and demand, is affected by regional differences in both the climate and the activities of the water user. To a large extent, users adapt to a perception of what is the normal supply for an area but there are other differences. A farmer, for example, is concerned with insufficient water during a season for crops, pastures and stock. A civil engineer in the same area may be more concerned with longer term aspects associated with the storage and managing of water in a reservoir.

On the supply side of the drought equation the main determinants are meteorological and hydrological. It is the former that is given emphasis in this article. A comprehensive coverage of Australia's water resources, including the impact of drought, is given in the series of publications, Water 2000 prepared for the Australian Water Resources Council in 1983. The broader subject of drought in Australia and the mitigation of its adverse effects has been the topic of many papers and symposia, for example, see the report and recommendations of a drought workshop held in Melbourne by the Royal Meteorological Society in 1986.

The amount of water available for the great majority of users depends on the storage, whether it be in the soil, farm dams, artesian basins, reservoirs and so on. In addition, water availability is affected by losses due to run-off, evaporation and wasteful usage. However the primary indicator of water availability in Australia is rainfall and, given its extensive measurement across the country, rainfall is the most suitable starting point to assess the incidence of drought.

One important aspect of rainfall or more specifically the lack of it, is the difference between aridity and drought, distinguished by Coughlan and Lee (1978) thus: **Aridity implies a high probability of rainfall for a given period below a low threshold. Drought implies a low probability of rainfall for a given period below a relatively low threshold.**

Thus establishing drought criteria is less meaningful for arid zones since the prospects of receiving useful rainfall are significantly lower there than in more abundant rainfall zones. During the dry seasons of the seasonal rainfall zones, e.g. northern Australia, the expectation of useful rainfall can also be quite low and one may think in terms of seasonal aridity. Defining drought criteria for areas with highly seasonal rainfall requires separate consideration and the problem of delineating the onset and retreat of drought in such areas can be quite complex.

## **PASTORAL DROUGHT AND CLIMATIC ZONES**

From a practical viewpoint then, drought is intrinsically related to climatic zones and to the resistance of plants to water shortages. Generally, natural pastures and herbage have evolved to become highly resistant to extended periods of low rainfall particularly in the arid zone. On the other hand, cereal crops such as wheat, being more sensitive to water limitations, require specific treatment in the establishment of criteria for drought.

There are many ways of delineating climatic zones. Those shown for Australia in the diagram on page 211 are based principally on seasonal rainfall characteristics, although evaporation has been taken into account to some extent in the derivation of the zonal boundaries (Bureau of Meteorology, 1975).

In the winter and uniform zones of Australia where agricultural and pastoral activities are more intensive, three consecutive months, although an arbitrary figure, has been found to be an appropriate minimum period for a significant deficiency in the rainfall to develop. Rainfall in the summer rainfall zone is generally more variable when compared with the winter and uniform zones. Coughlan and Lee (1978) have used the summer rainfall zone in northern Australia to illustrate how probabilities of water stress in sown crops may be affected by the expected variability within any one season. Native pastures, in contrast, have evidently evolved to respond more effectively to seasonal rainfall as a whole and are less likely to be affected by the distribution of variable quantities throughout the season. Soil type and the degree to which it has been worked are also significant factors in this regard.

Rainfall in arid zones, as well as being low, is usually highly variable in space and time, and natural pastures and herbage are strongly resistant to such stresses. Drought in an arid zone is generally more appropriate to longer periods, e.g. a year or more, rather than to periods as short as three consecutive months.

## **RAINFALL DEFICIENCY AND THE AUSTRALIAN DROUGHT WATCH SERVICE**

There have been many attempts to arrive at a satisfactory method of objectively defining drought, establishing criteria for its onset, monitoring its course and declaring a drought ended. Perhaps the most successful approach, and one of the simplest in concept, uses the first decile of accumulated rainfall for a given period as an indicator of drought (Gibbs and Maher, 1967; Lee and Gaffney, 1986). The first decile is simply that amount of rainfall which is exceeded on ninety per cent of occasions for the period of the year specified, e.g. winter, spring or indeed any period of consecutive months. The concept of rainfall deficiency employed by the Bureau of Meteorology is based on a comparison of the rainfall total for at least three months in a specific area with the historical long period record for those three or more months. Thus an area is

categorised as having a rainfall deficiency when the rainfall for a period of at least three months falls within the lowest ten per cent (below the first decile) of the historically recorded rainfalls for the same period of the year.

The terms serious and severe rainfall deficiency are defined as follows:

- **a serious rainfall deficiency** exists for a specific period of three (or more) months when the rainfall is above the lowest five per cent of recorded rainfalls, but is less than the ten per cent value;
- a severe rainfall deficiency exists for a specific period of three (or more) months when the rainfall is among the lowest five per cent of recorded rainfalls.

When serious or severe deficiencies exist in an area they continue as such until:

(a) rainfall for the past month is already sufficient to rank in the 30th percentile or greater of the recorded rainfalls for the three month period starting with that month (a break due to relatively heavy rainfall), or

(b) rainfall for the past three months ranks in the 70th percentile or greater of the recorded rainfalls for the corresponding three month period (a break due to a series of lesser but overall significant falls).

Rainfall deficiency criteria based on decile values provide the basis for alerting to incipient drought and monitoring the course of extant drought. The procedures, which have been in use in Australia since 1965, have also been adopted by the World Meteorological Organization to monitor drought on a worldwide scale (World Meteorological Organization, 1985). The Drought Watch Service, operated by the National Climate Centre in the Bureau of Meteorology, uses rainfall data from around 800 individual stations throughout the country to provide a monthly statement supported by maps and figures on the distribution of existing rainfall deficiencies (Coughlan, 1986).

## MAJOR DROUGHTS IN AUSTRALIA

Foley (1957), on the basis of rainfall analyses, classified major droughts in Australia from the early period of European settlement to 1955. He referred to these droughts, summarised in Table 1, as major, severe and widespread and his broad descriptive material indicates that each affected several States covering about one quarter of Australia or more, for varying periods of one or more years. Some of these droughts could be described as drought periods consisting of a series of dry spells of various lengths, overlapping in time and space, and totalling up to about a decade, as in the case of the 1895-1903 drought.

Subsequent to Foley's work, major droughts in Australia have been assessed from time to time using rainfall decile analyses. Typically they have been described as areas of at least serious rainfall deficiency (below the first decile), collectively encompassing at least one quarter of Australia for periods in excess of 10 months. The drought period of 1958-68 and the drought of 1982-83 met these criteria.

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## MAJOR DROUGHTS IN AUSTRALIA

Drought period (a)	Description
<b>1864 - 66 (and 1868).</b>	The little data available indicate that this drought period was rather severe in Victoria, South Australia, New South Wales, Queensland and Western Australia.
<b>1880 - 86</b>	Victoria (northern areas and Gippsland); New South Wales (mainly northern wheat belt, northern tablelands and south coast); Queensland (1881-86, in south-east with breaks - otherwise mainly in coastal areas, the central highlands and central interior in 1883-86); and South Australia (1884-86, mainly in agricultural areas).
<b>1888</b>	Victoria (northern areas and Gippsland); Tasmania (1887-89 in the south); New South Wales; Queensland (1888-89); South Australia and Western Australia (central agricultural areas).
<b>1895 - 1903</b>	Practically the whole of Australia was affected but most persistently the coast of Queensland, inland areas of New South Wales, South Australia, and central Australia. This was probably Australia's worst drought to date in terms of severity and area. Sheep numbers, which had reached more than 100 million, were reduced by approximately half and cattle numbers by more than 40 per cent. Average wheat yields exceeded 8 bushels per acre in only one year of the nine, and dropped to 2.4 bushels per acre in 1902.
<b>1911 - 16</b>	Victoria (1913-15 in north and west); Tasmania (1913-15); New South Wales, particularly inland areas; Queensland; Northern Territory (mainly in the Tennant Creek-Alexandria Downs area); South Australia (some breaks in agricultural areas); and Western Australia (1910-14).
<b>1918 - 20</b>	Queensland, New South Wales, South Australia, Northern Territory (Darwin-Daly Waters area and central Australia), Western Australia (Fortescue area), Victoria, and Tasmania.
<b>1939 - 45</b>	New South Wales (severe on the coast), South Australia (persistent in pastoral areas), Queensland and Tasmania; also (more particularly in 1940 and 1944-45) in Western Australia, Victoria, and central Australia; Tennant Creek-Alexandria Downs area in 1943-45.
<b>1958 - 68</b>	This drought was most widespread and probably second to the 1895-1903 drought in severity. For more than a decade from 1957, drought was consistently prominent and frequently made news headlines from 1964 onwards. This was treated as one major drought period, but could be subdivided into two which overlapped, both in time and space. Central Australia and vast areas of adjacent Queensland, South Australia, Western Australia, New South Wales, and northern Australia were affected, with varying intensity, 1957-66; and south eastern Australia experienced a severe drought, 1964-68.
<b>1982 - 83</b>	This extensive drought affected nearly all of eastern Australia, and was particularly severe in south eastern Australia. Lowest ever 11 month rainfall occurred over most of Victoria and much of inland New South Wales and central and southern Queensland; and lowest ever 10 month rainfall occurred in much of South Australia and northern Queensland. Total losses were estimated in excess of \$3,000 million.

(a) Major droughts to 1939-45 were classified by Foley (1957). Subsequent droughts were classified by the Drought Watch Criteria (1986).

Australia's most severe drought periods since the beginning of European settlement appear to

have been those of 1895-1903 and 1958-68. The 1982-83 drought was possibly the most intense with respect to the area affected by severe rainfall deficiencies. These periods were comparable in their overall impact, but differed appreciably in character.

The 1895-1903 drought period was probably Australia's worst to date, in terms of both its severity and area - affecting practically the whole of Australia at various times but more persistently in parts of eastern and central Australia. Stock and crop losses were apparently the highest in Australian history.

The 1958-68 drought period is described in the article contained in the 1968 Year Book No. 54. That drought period was widespread and probably second only to the 1895-1903 drought period in severity. The areas affected and their duration's of drought were variable and overlapping.

The 1982-83 drought was notably severe also, especially in south-eastern Australia. This drought was monitored closely and is discussed more fully below.

Droughts of a lesser degree of severity categorised by Foley (1957) are given in Table 2. The droughts of 1970-73 and 1976 were analysed by rainfall deficiency methods based on decile analysis and are appropriate for inclusion in this category.

## DROUGHTS IN AUSTRALIA OF LESSER SEVERITY

Drought period (a)	Description
<b>1922 - 23 and 1926 - 29</b>	Queensland (severe); New South Wales (intermittent); Western Australia (more particularly Fortescue: 1922-29); South Australia (mainly pastoral areas); central Australia (1924-29); Northern Territory (1926-29); Victoria (1925-27; severe in the north 1925-29) and Tasmania (1925-27, not continuous).
<b>1933 - 38</b>	Western Australia (severe in pastoral and northern agricultural areas); Queensland (breaks on the coast); Victoria (north and Gippsland); New South Wales (not continuous except on the northern tablelands); Northern Territory; South Australia (1935-36 in pastoral areas and 1938 in agricultural areas) and northern Tasmania (1935-37, not continuous).
<b>1946 - 49</b>	Queensland (central coast and highlands and central interior, elsewhere mainly in 1946); Northern Territory and New South Wales (mainly in 1946-47); Western Australia (more particularly in central agricultural areas, 1947-50), and northern Tasmania (1948-49).
<b>1951 - 52</b>	Queensland and Northern Territory; and Western Australia, especially pastoral areas (1951-54).
<b>1970 - 73</b>	Prolonged drought over the north-eastern goldfields of Western Australia and adjacent areas, caused by successive below average rainfall years.
<b>1976</b>	Western New South Wales, most of Victoria and South Australia due to failure of autumn-winter rains; break in September 1976.

(a) The drought to 1951-52 inclusive, were classified by Foley (1957). The subsequent droughts, 1970-73 and 1976, were classified by the Drought Watch Criteria (1986)

## Severe droughts in south-eastern Australia

South-eastern Australia is taken to include New South Wales, southern Queensland, Victoria, Tasmania and the settled parts of South Australia; it contains about 75 per cent of the nation's population, and major droughts affecting the region have a markedly adverse impact on the economy. Severe droughts in south-eastern Australia are usually caused by a failure of the winter-spring rains and may extend through summer to the following autumn.

A severe drought is defined here in general terms as a drought in which ten or more rainfall districts are substantially affected by rainfall deficiencies for eight or more months. The onset of drought is taken as the month in which rainfall drops below average, and which marks the start of a period with serious rainfall deficiencies (below the first decile) lasting three months or more. A drought is considered broken when rainfall meets the criteria defined previously.

### SEVERE DROUGHTS IN SOUTH-EASTERN AUSTRALIA

Drought period (a)	Area affected	Average duration and month of break	Descriptive remarks
1888	Southern Queensland, most of New South Wales, Victoria, South Australia and parts of Tasmania	9-10 months to January 1889	In parts of northern New South Wales, not broken until autumn 1889
1902	New South Wales, Victoria, parts of southern Queensland, South Australia and Tasmania	Victoria, South Australia and Tasmania: 9 months to December 1902 New South Wales and southern Queensland 12 months to 1902	Considerable overlapping of affected areas
1914-15	Victoria, New South Wales west of the tablelands, settled areas of South Australia and most of Tasmania	South Australia 11-12 months to June 1915 Northern Victoria and New South Wales 10-12 months to June/July 1915 Southern Victoria 16 months to May/June 1915	Rainfall during 1913 also below average in parts of south-eastern Australia; and much of Victoria and western New South Wales had some relief in the summer of 1914-15
1940-41	Most of New South Wales, Victoria, South Australia and eastern Tasmania	South Australia 6 months to January 1941 Tasmania 8-9 months to January 1941 Victoria 11 months to January	Variable durations in New South Wales
1944-45	Most of New South Wales, Victoria and South Australia	South Australia and south-western Victoria 4-6 months to summer 1944-45	Well below average rainfall in parts of South Australia in April-June 1945; and

		Southern Victoria 12 months to August 1945 Northern Victoria and southern New South Wales 15-19 months to August 1945 Northern New South Wales 15-17 months to June 1945	1943 was also a dry year in parts of south-eastern Australia
<b>1967-68</b>	Victoria, southern New South Wales, South Australia and Tasmania	South Australia 12- 13 months to March 1968 Tasmania 15- 16 months to May 1968 Victoria and New South Wales 14 - 15 months to May 1968	Other extensive parts of Australia affected during 1958-67
<b>1972-73</b>	Most of Victoria, western and central New South Wales, South Australia and north eastern Tasmania	9-10 months ending February 1973	Drought broke in February 1973; except in north-eastern Tasmania, where it broke in autumn 1973
<b>1982-83</b>	Victoria, most of New South Wales, South Australia, southern Queensland and Tasmania	Generally 11 months ending February 1983 Tasmania: 9 months ending February 1983	Drought broke in autumn 1983

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(a) The drought periods prior to 1965 inclusive, occurring prior to the operation of the Drought Watch Criteria, have been re-assessed applying those criteria. The specified severe droughts in south eastern Australia are actually encompassed within the major droughts in Australia contained in Table I (except 1972-73).

These past, severe droughts were investigated (Bureau of Meteorology, 1983) using seasonal rainfalls over south-eastern Australia based on a limited network of rainfall stations and previously published material. Droughts after 1914 were identified using also the district rainfall data. Two earlier droughts affected south-eastern Australia, in 1864-66 and 1880-86, but rainfall data for these are incomplete. The 1918-20 period was also significantly drought affected without quite meeting the criteria.

Of these eight severe droughts in south-eastern Australia, four ended in summer (1888, 1902, 1940-41, 1972-73). Two droughts (1967-68 and 1982-83) broke in autumn. The remaining two (1914-15 and 1944-45) generally persisted until the following winters, although there were useful summer rains over a significant portion of the drought affected areas.

### **The 1982-83 major drought**

The following figure indicates the severity and extent of the 1982-83 major drought in terms of rainfall deficiency over the extensive areas where rainfall for the duration of the drought, approximately ten to eleven months, was the lowest on record. This was due to a widespread failure of the winter and spring rains of 1982. By the end of February 1983, in this vast area of eastern Australia, only small parts of south-east Queensland, adjacent north-east New South

Wales and parts of south-west and north-east Tasmania were free from drought.

In the far south-eastern part of the continent the drought was markedly severe. Virtually all of Victoria and southern New South Wales had registered record low rainfall for the eleven months, April 1982-February 1983 inclusive. Much of the settled areas of South Australia had recorded their lowest ever rainfall for the ten months, May 1982-February 1983 inclusive.

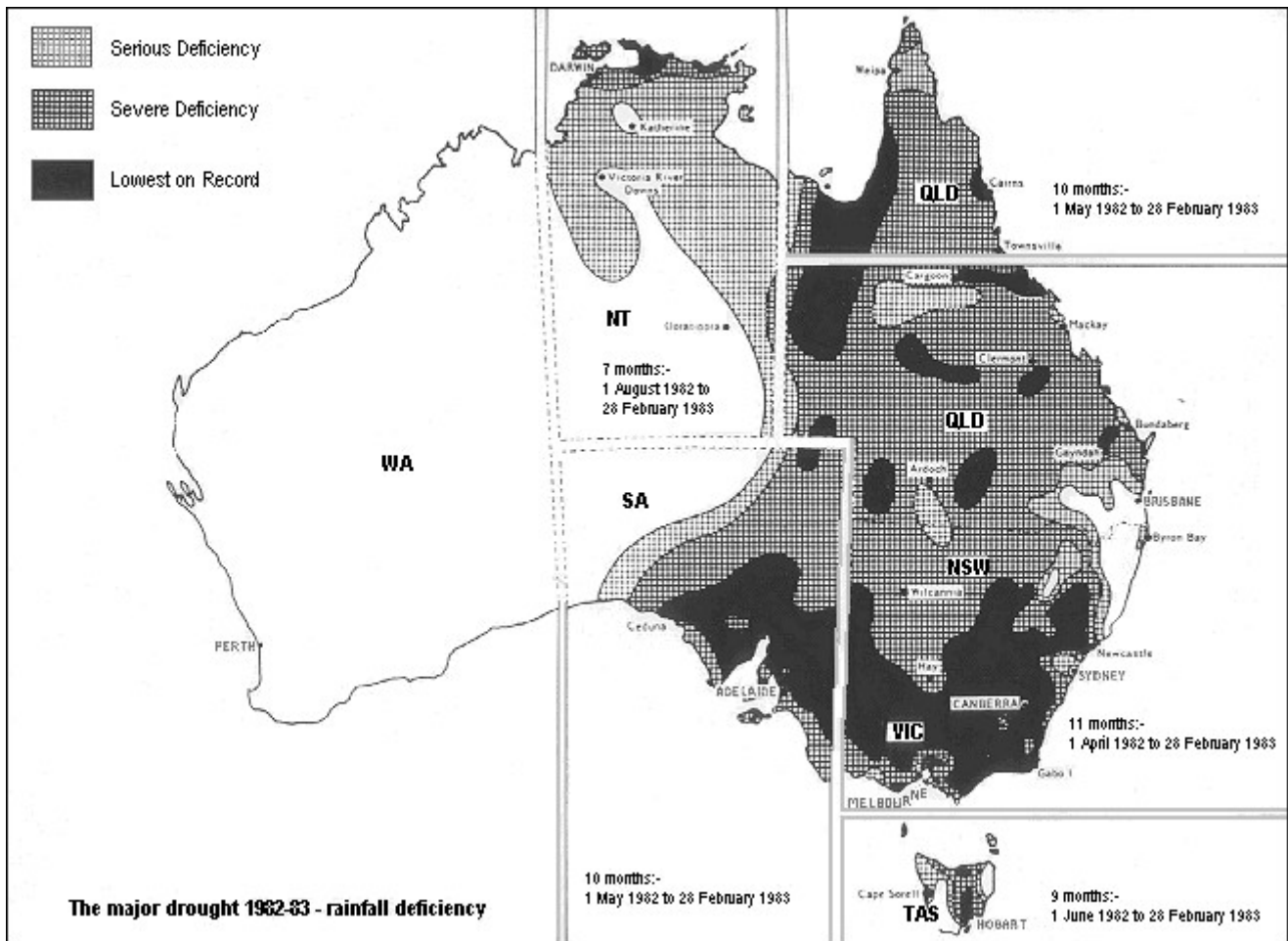
It is generally agreed that the widespread bushfires which culminated in the enormous conflagrations of Ash Wednesday, 16 February 1983, were a direct consequence of the preceding drought conditions. Total losses caused by the drought were estimated by the Australian Government to exceed \$3,000 million; and estimates of losses in south-eastern Australia exceeded \$1,200 million.

Widespread heavy rains in March 1983 significantly reduced the extent of the drought over eastern Australia. Heavy April rains further decreased the area of the drought, and record May rains left only small scattered remnants at the end of autumn 1983.

## **PHYSICAL CAUSES OF DROUGHT**

The physical causes of drought, as distinct from the socio-economic factors that may induce stress in association with below average rainfall (e.g. see Coughlan, 1985), have their origins in the fluctuations of the global climate system. There are many possible reasons why the weather during a particular month or season will differ from one year to the next. The climate system as a whole is an extremely complex mix of different sub-systems all interacting with each other on a wide range of time and space scales, e.g. the atmosphere, oceans, ice masses and the biosphere. The potential for variability from year to year and decade to decade therefore is very high. Given this high level of 'internal' variability, the significance or even the reality of possible external influences from sunspots, phases of the moon and so on, remains highly questionable on time scales shorter than millennia.

The fact that variability in time and space is an inherent character of the climate means that droughts of varying extent and severity must also be an inherent part of this variability. With an increase in understanding of how the various parts of the climate system fit together and interact with each other, is coming a greater understanding at least of what causes the larger scale droughts. Perhaps the most widely known climatic anomaly that has developed every few years is the so-called El-Nino phenomenon. El-Nino, a name given to an anomalous warm ocean current off the equatorial Pacific coast of South America is part of a much wider system affecting the whole of the Pacific Basin and probably the whole globe. The appearance of an El-Nino is very often associated with below average rainfall over much of eastern Australia. El-Nino is linked to a swing in the mean atmospheric pressure difference across the Pacific Ocean called the Southern Oscillation. Many of the widespread and severe droughts affecting eastern Australia identified above were a direct consequence of a marked swing in the Southern Oscillation.



## MONITORING THE WEATHER AND CLIMATE

With a growing international awareness of the social and economic impacts of climate variability, including drought, the World Meteorological Organization (WMO) in the late 1970s instituted a World Climate Programme (WCP) to complement its long established World Weather Watch Programme. The WCP is the formal framework for international co-operation in climate data exchange, climate monitoring, applications of climate data, climate research and the impacts of climate variability on man and the environment. As a national focus, some countries (e.g. U.S.A and Canada) have established National Climate Programs.

Australia's Bureau of Meteorology plays a key role in international data exchange and analysis by operating in Melbourne one of the three World Meteorological Centres (WMC), the other two centres being in Washington and Moscow. The Melbourne WMC and a Regional Meteorological Centre in Darwin, also operated by the Bureau, collect and process weather and climate data for the southern hemisphere. These Centres issue daily weather analyses and forecasts for the southern hemisphere, eastern Asia and the western equatorial Pacific.

The National Climate Centre (NCC), in addition to its monitoring of fluctuations in Australia's climate, carries out analyses of monthly and seasonal variations of atmospheric pressure, temperature and wind over the southern hemisphere as a whole. The analyses are contained in the NCC's monthly Climate Monitoring Bulletin accompanied by seasonal indications, outlooks and inferences when feasible. Information is regularly exchanged between similar climate centres operating in other countries.

The Bureau of Meteorology Research Centre has also instituted a program of research into the problems of forecasting climate fluctuations on monthly and seasonal time scales. Any

improvements in this regard would have far reaching implications for our ability to cope with drought. Already there are signs of some skill in using the new found knowledge of the Southern Oscillation/El-Nino phenomenon to assess the likelihood of major anomalies in winter/spring rainfall over eastern Australia several months in advance.

## CONCLUSION

Since the 1860s there have been nine major Australian droughts. The major drought periods of 1895-1903 and 1958-68 and the major drought of 1982-83 were the most severe in terms of rainfall deficiency and their effects on primary production. In south-eastern Australia the droughts of 1967-68 and 1982-83 were notably extreme. There have been six other droughts of a lesser degree of intensity, but nevertheless causing appreciable losses in large areas of several States. In south-eastern Australia there have been eight severe droughts, mostly encompassed within the major Australian droughts.

Droughts will continue to be a prominent feature of the Australian scene. Improved meteorological drought watch services and hopefully an improved ability to forecast droughts through local research and participation in the WCP will help to mitigate their adverse impacts. The nature of drought, however, and the way in which the community should deal with it are complex issues incorporating significant variables in fields such as hydrology, agriculture, economics and sociology, as well as in the political realities of the day.

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This page last updated 22 November 2012

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